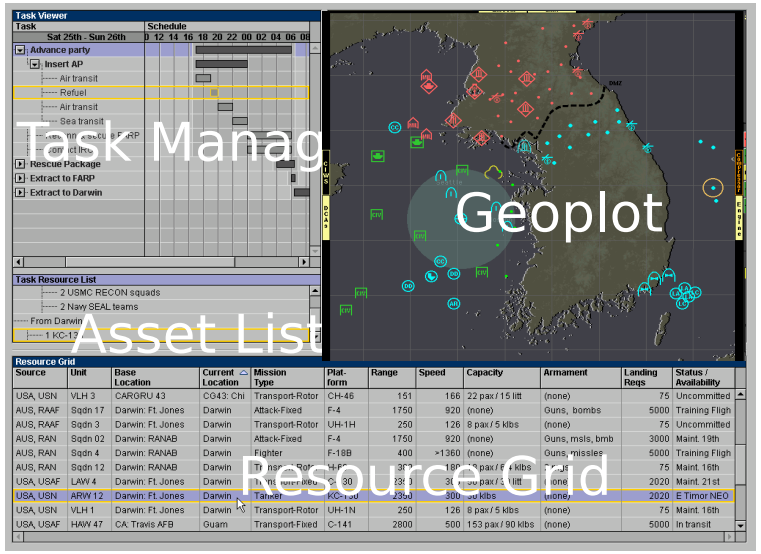
Some Human Factors Design Principles for Effective Visualization and Collaboration of Military Operations



OFFICE OF NAVAL RESEARCH

SPAWAR
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Pacific Science & Engineering

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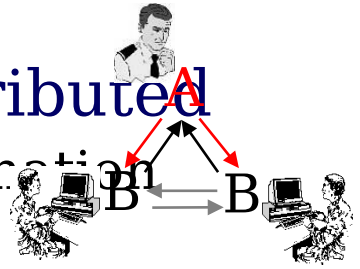
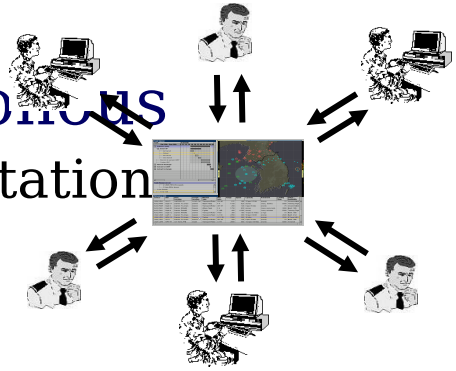
Collaboration in Military Command and Control

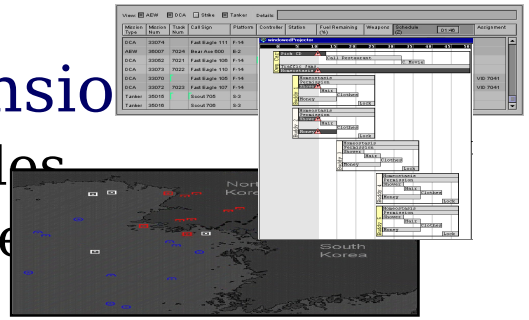
- Interactions are hierarchical and distributed
  - Need information sharing and plan coordination



- Interactions are asynchronous
  - Need intervening representation

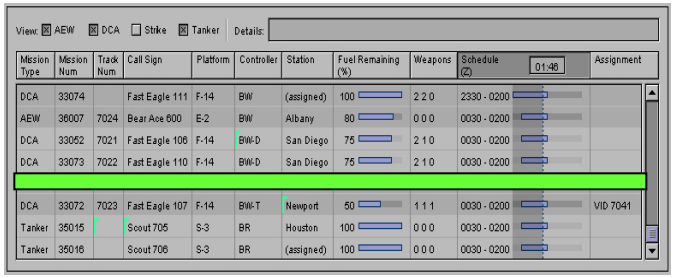


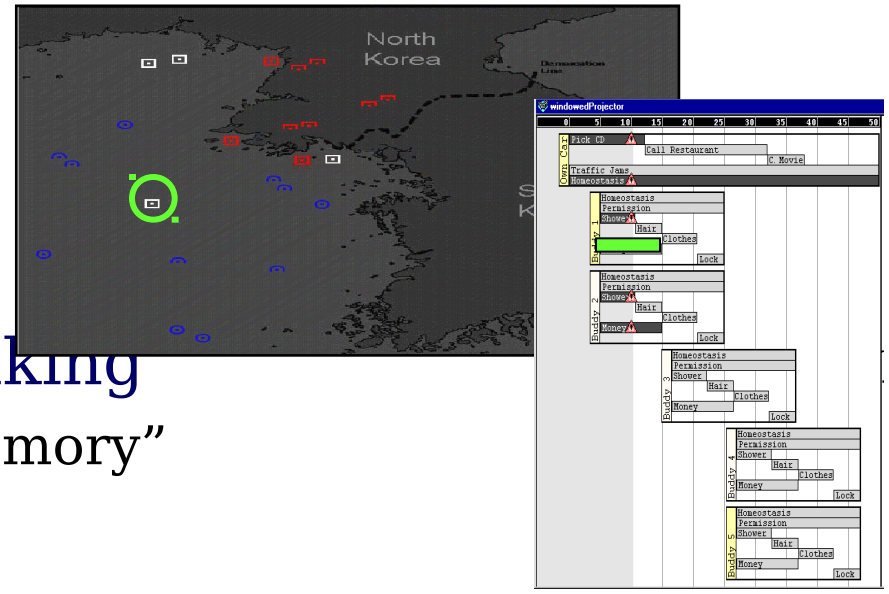
- Plans are complex and many dimensio
  - Goals, tasks, assets, priorities, schedules
  - Need information visualization and inte



Architecture Principle: Slice & Link

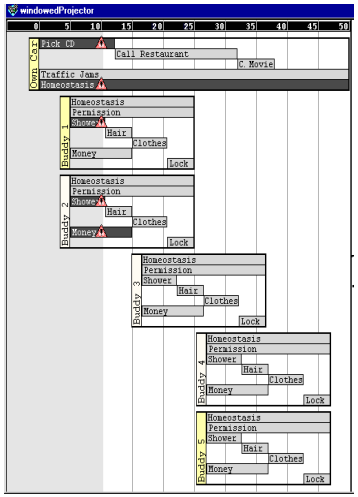
- Use multiple “2D” displays
  - Geoplot
    - Assets by location
  - Task Manager
    - Tasks by time
  - Resource Grid
    - Assets by attribute
  - Etc.
- Use Dynamic Visual Linking
  - “Content addressable memory”


View: AEW DCA Strike Tanker Details:
Mission Type
Mission Num
Track Num
Call Sign
Platform
Controller
Station
Fuel Remaining (%)
Weapons
Schedule (Z)
01:46
Assignment
DCA 33074 Fast Eagle 111 F-14 BW (assigned) 100 2 2 0 2330 - 0200
AEW 36007 7024 Bear Ace 600 E-2 BW Albany 80 0 0 0 0030 - 0200
DCA 33052 7021 Fast Eagle 106 F-14 BW-D San Diego 75 2 1 0 0030 - 0200
DCA 33073 7022 Fast Eagle 110 F-14 BW-D San Diego 75 2 1 0 0030 - 0200
DCA 33072 7023 Fast Eagle 107 F-14 BW-T Newport 50 1 1 1 0030 - 0200 VID 7041
Tanker 35015 Scout 705 S-3 BR Houston 100 0 0 0 0030 - 0200
Tanker 35016 Scout 706 S-3 BR (assigned) 100 0 0 0 0030 - 0200

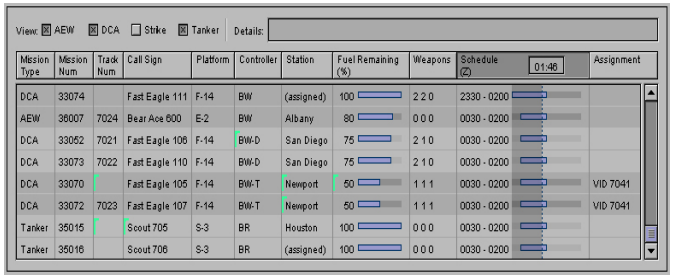


“2D” Display Design

- Task Manager
  - Task by time
  - Schedules
  - Dependencies
  - Implications of delays
  - Etc.



- Resource Grid
  - Assets by attributes
  - Sort, filter, retrieve, compare assets and their attributes


View: AEW DCA Strike Tanker Details:
Mission Type
Mission Num
Track Num
Call Sign
Platform
Controller
Station
Fuel Remaining (%)
Weapons
Schedule (Z)
01:46
Assignment
DCA 33074 Fast Eagle 111 F-14 BW (assigned) 100 2 2 0 2330 - 0200
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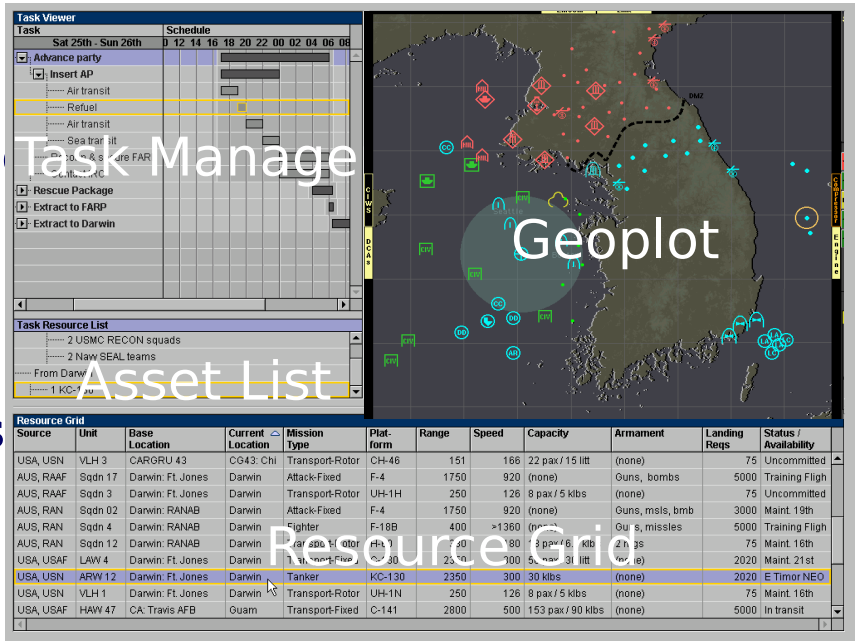
DCA 33052 7021 Fast Eagle 106 F-14 BW-D San Diego 75 2 1 0 0030 - 0200
DCA 33073 7022 Fast Eagle 110 F-14 BW-D San Diego 75 2 1 0 0030 - 0200
DCA 33070 Fast Eagle 105 F-14 BW-T Newport 50 1 1 1 0030 - 0200 VID 7041
DCA 33072 7023 Fast Eagle 107 F-14 BW-T Newport 50 1 1 1 0030 - 0200 VID 7041
Tanker 35015 Scout 705 S-3 BR Houston 100 0 0 0 0030 - 0200
Tanker 35016 Scout 706 S-3 BR (assigned) 100 0 0 0 0030 - 0200

PSYCLOPS

A Single Integrated “Eye” on the Situation

- Integrated Tools to Augment Command and Control
  - More effective situation and plan visualization tools with
  - Visually interlinked databases for content addressable memory and context tracking
- Linked components
  - Task Manager
    - Task components and sche
  - Resource Grid
    - Asset data and availability
  - Asset List
    - Correlation of assets to tas
  - Geoplot
    - Locations of assets

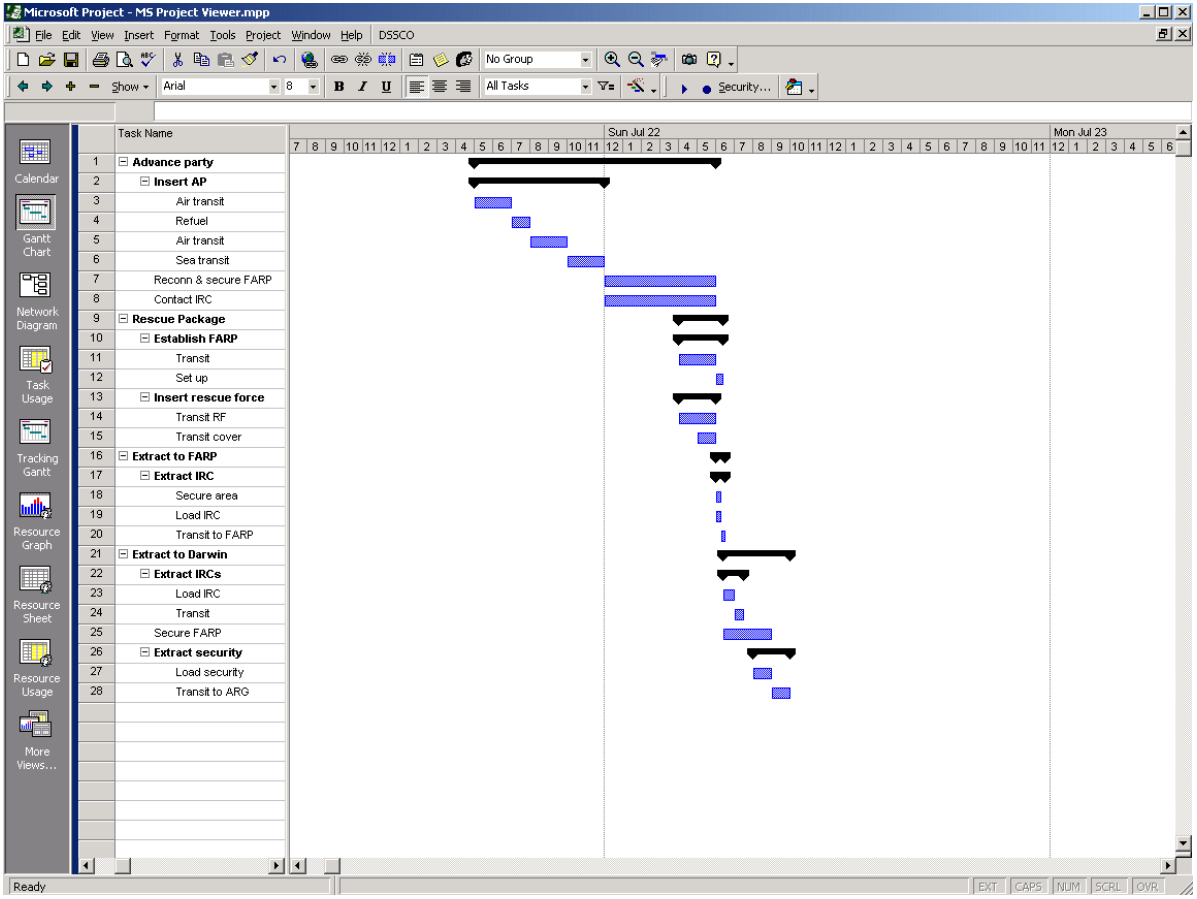

Task Viewer
Task
Schedule
Sat 25th - Sun 26th
Advance party
Insert AP
Air transit
Refuel
Air transit
Rescue Package
Extract to FARP
Extract to Darwin
Task Resource List
2 USMC RECON squads
2 Navy SEAL teams
Task Manage
Geoplot
Asset List
Resource Grid
Source
Unit
Base Location
Current Location
Mission Type
Plat-form
Range
Speed
Capacity
Armament
Landing Reqs
Status / Availability
USA, USN VLH 3 CARGRU 43 CG43: Chi Transport-Rotor CH-46 151 166 22 pax / 15 litt (none) 75 Uncommitted
AUS, RAAF Sqdn 17 Darwin: Ft. Jones Darwin Attack-Fixed F-4 1750 920 (none) Guns, bombs 5000 Training Fligh
AUS, RAAF Sqdn 3 Darwin: Ft. Jones Darwin Transport-Rotor UH-1H 250 126 8 pax / 5 klbs (none) 75 Uncommitted
AUS, RAN Sqdn 02 Darwin: RANAB Darwin Attack-Fixed F-4 1750 920 (none) Guns, msls, bmb 3000 Maint. 19th
AUS, RAN Sqdn 4 Darwin: RANAB Darwin Fighter F-18B 400 >1360 (none) Guns, missles 5000 Training Fligh
AUS, RAN Sqdn 12 Darwin: RANAB Darwin 75 Maint. 16th
USA, USAF LAW 4 Darwin: Ft. Jones Darwin 2020 Maint. 21st
USA, USN ARW 12 Darwin: Ft. Jones Darwin Tanker KC-130 2350 300 30 klbs (none) 2020 E Timor NEO
USA, USN VLH 1 Darwin: Ft. Jones Darwin Transport-Rotor UH-1N 250 126 8 pax / 5 klbs (none) 75 Maint. 16th
USA, USAF HAW 47 CA: Travis AFB Guam Transport-Fixed C-141 2800 500 153 pax / 90 klbs (none) 5000 In transit

Example Scenario: NEO in East Timor

- Noncombatant Evacuation Operation
  - CH-53s, CH-46s, KC-130s, AC-130s, MC-130s, AV-8Bs, AH-1s, USMC RECON teams, Navy SEAL teams, Medical corps teams
- Evacuate approx. 50 Red Cross workers from rebel-held territory in East Timor
- Work with local embassy to develop an evacuation plan
- Insert advance forces to recon and secure staging areas
- Insert main body rescue force
- Extract Red Cross workers and the rescue force

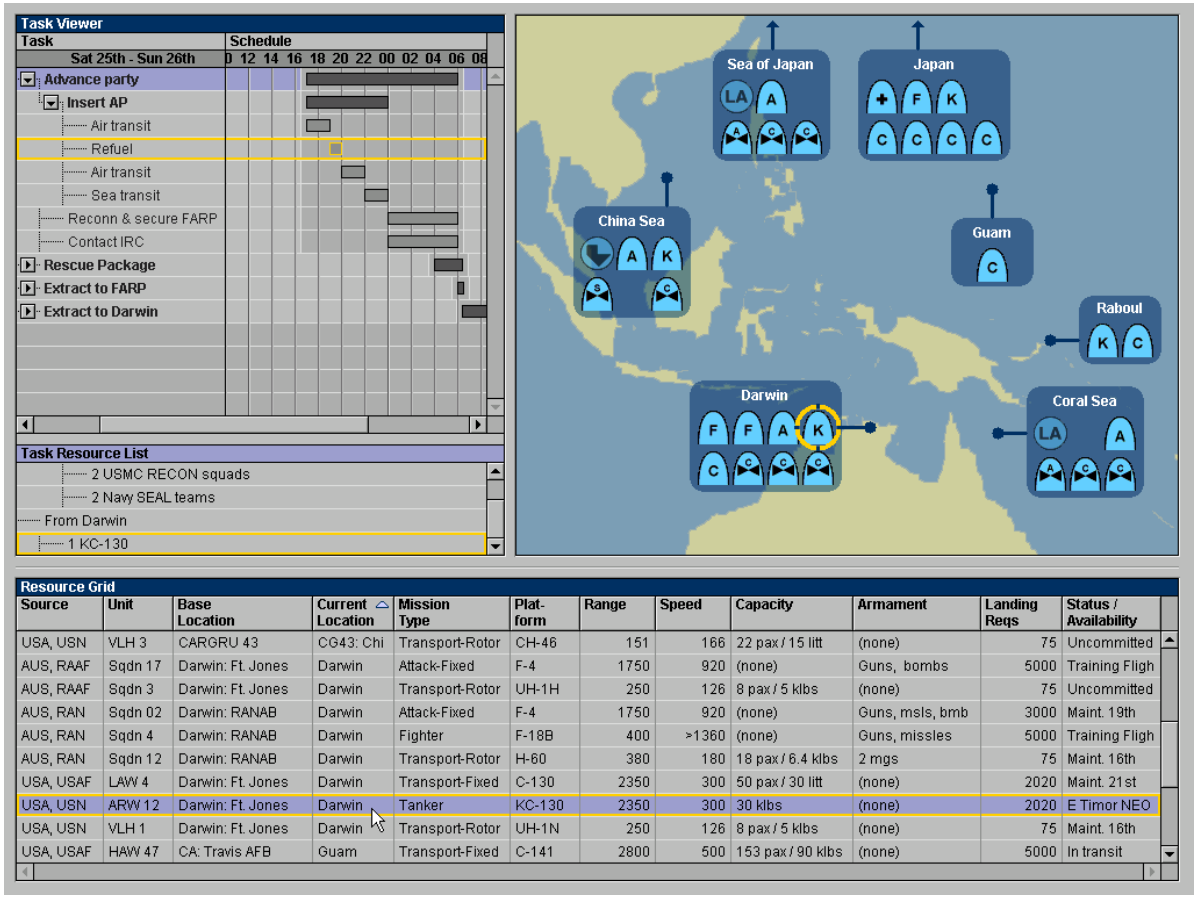
NEO with Current Tools

- Are there Darwin-based tasks or resources?
- What would it mean if there were?
- Do I need to reassign anything?
- How will I find replacement resources?
- Which tasks need rescheduling?



NEO with PSYCLOPS

- Are there Darwin-based tasks or resources?
- What would it mean if there were?
- Do I need to reassign anything?
- How will I find replacement resources?
- Which tasks need rescheduling?


Task Viewer
Task
Schedule
Sat 25th - Sun 26th
0 12 14 16 18 20 22 00 02 04 06 08
Advance party
Insert AP
Air transit
Refuel
Air transit
Sea transit
Reconn & secure FARP
Contact IRC
Rescue Package
Extract to FARP
Extract to Darwin
Task Resource List
2 USMC RECON squads
2 Navy SEAL teams
From Darwin
1 KC-130
Sea of Japan
Japan
China Sea
Guam
Raboul
Darwin
Coral Sea
Resource Grid
Source
Unit
Base Location
Current Location
Mission Type
Plat-form
Range
Speed
Capacity
Armament
Landing Reqs
Status / Availability
USA, USN VLH 3 CARGRU 43 CG43: Chi Transport-Rotor CH-46 151 166 22 pax / 15 litt (none) 75 Uncommitted
AUS, RAAF Sqdn 17 Darwin: Ft. Jones Darwin Attack-Fixed F-4 1750 920 (none) Guns, bombs 5000 Training Fligh
AUS, RAAF Sqdn 3 Darwin: Ft. Jones Darwin Transport-Rotor UH-1H 250 126 8 pax / 5 klbs (none) 75 Uncommitted
AUS, RAN Sqdn 02 Darwin: RANAB Darwin Attack-Fixed F-4 1750 920 (none) Guns, msls, bmb 3000 Maint. 19th
AUS, RAN Sqdn 4 Darwin: RANAB Darwin Fighter F-18B 400 >1360 (none) Guns, missles 5000 Training Fligh
AUS, RAN Sqdn 12 Darwin: RANAB Darwin Transport-Rotor H-60 380 180 18 pax / 6.4 klbs 2 mgs 75 Maint. 16th
USA, USAF LAW 4 Darwin: Ft. Jones Darwin Transport-Fixed C-130 2350 300 50 pax / 30 litt (none) 2020 Maint. 21st
USA, USN ARW 12 Darwin: Ft. Jones Darwin Tanker KC-130 2350 300 30 klbs (none) 2020 E Timor NEO
USA, USN VLH 1 Darwin: Ft. Jones Darwin Transport-Rotor UH-1N 250 126 8 pax / 5 klbs (none) 75 Maint. 16th
USA, USAF HAW 47 CA: Travis AFB Guam Transport-Fixed C-141 2800 500 153 pax / 90 klbs (none) 5000 In transit

METOC: “Bad weather in Darwin”

Task Viewer

Task	Schedule
Sat 25th - Sun 26th	02 04 06 08 10 12 14 16 18 20 22
Advance party	
Rescue Package	
Extract to FARP	
Extract to Darwin	

Task Resource List

Resource Grid

Source	Unit	Base Location	Current Location	Mission Type	Plat-form	Range	Speed	Capacity	Armament	Landing Reqs	Status / Availability
USA, USAF	HAW 47	CA: Travis AFB	Guam	Transport-Fixed	C-141	2800	500	153 pax / 90 klbs	(none)	5000	In transit
USA, USAF	HAW 23	Okinawa	Okinawa	Transport-Fixed	C-141	2800	500	153 pax / 90 klbs	(none)	5000	Team Spirit
USA, USAF	LAW 4	Darwin: Ft. Jones	Darwin	Transport-Fixed	C-130	2350	300	50 pax / 30 litt	(none)	2020	Maint. 21st
USA, USAF	MAW 8	Kadena AB: Japan	Kadena	Transport-Fixed	C-17	2760	390	102 pax / 90 klbs	(none)	4700	Team Spirit
USA, USAF	MAW 3	Yokota AB: Japan	Yokota	Transport-Fixed	C-130	2350	300	74 pax / 25 klbs	(none)	2020	Team Spirit
USA, USMC	AW 3	Okinawa	Okinawa	Transport-Fixed	MC-130	2350	300	74 pax / 25 klbs	(none)	2020	Team Spirit
USA, USN	VAS 22	CARGRU 43	CG43: Chi	ASW-Rotor	SH-60	150	155	3 torp	3 torpedos	75	Uncommitted
USA, USN	TF 33	ARG: Belleau Wood	ARG: Coral	Attack-Fixed	AV-8B	800	630	(none)	Guns, msls, bmb	100	E Timor NEO
USA, USN	TF 57	ARG: Tarawa	ARG: Sea	Attack-Fixed	AV-8B	800	630	(none)	Guns, msls, bmb	75	Team Spirit
USA, USN	TF 33	ARG: Belleau Wood	ARG: Coral	Attack-Rotor	AH-1	317	173	(none)	Guns, msls, bmb	75	E Timor NEO

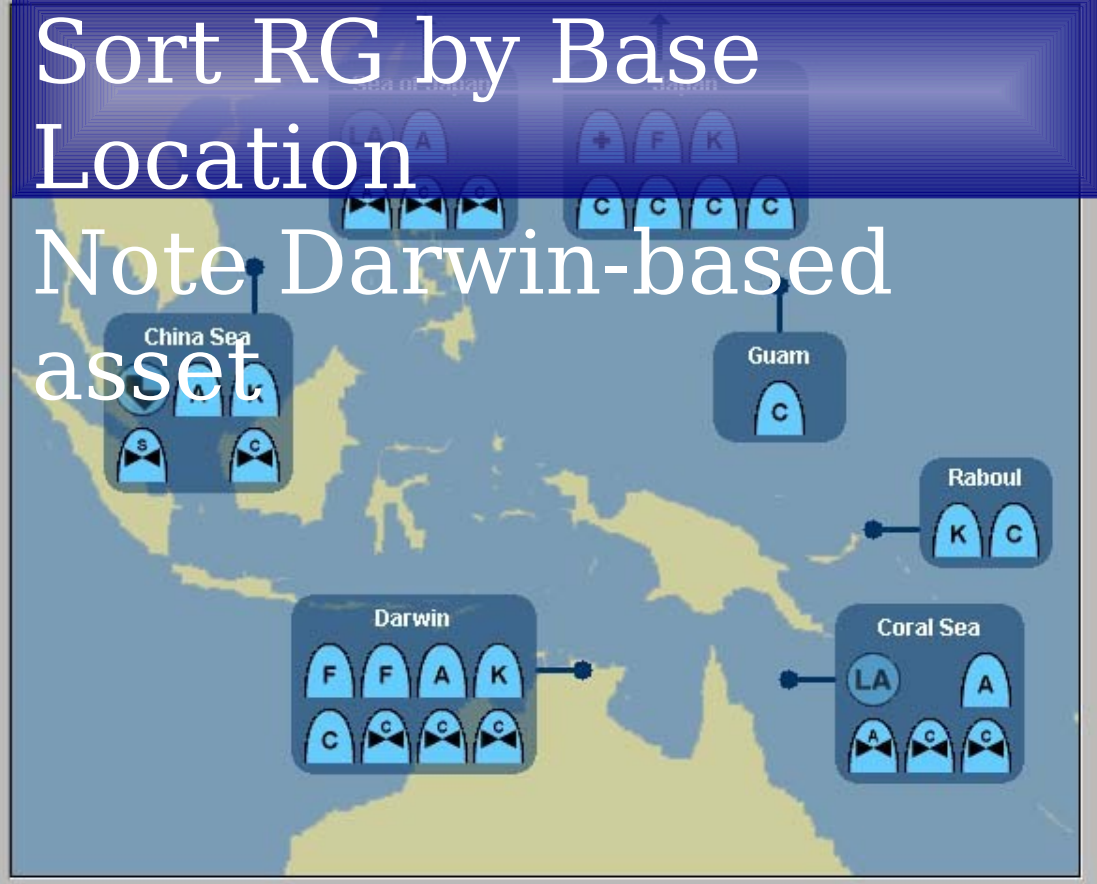
Sort RG by Base Location

Note Darwin-based asset

Task Viewer

Task	Schedule
Sat 25th - Sun 26th	02 04 06 08 10 12 14 16 18 20 22
Advance party	
Rescue Package	
Extract to FARP	
Extract to Darwin	

Task Resource List



Resource Grid

Source	Unit	Base Location	Current Location	Mission Type	Plat-form	Range	Speed	Capacity	Armament	Landing Reqs	Status / Availability
USA, USN	VLH 3	CARGRU 43	CG43: Chi	Transport-Rotor	CH-46	151	166	22 pax / 15 litt	(none)	75	Uncommitted
AUS, RAAF	Sqdn 17	Darwin: Ft. Jones	Darwin	Attack-Fixed	F-4	1750	920	(none)	Guns, bombs	5000	Training Fligh
AUS, RAAF	Sqdn 3	Darwin: Ft. Jones	Darwin	Transport-Rotor	UH-1H	250	126	8 pax / 5 klbs	(none)	75	Uncommitted
USA, USAF	LAW 4	Darwin: Ft. Jones	Darwin	Transport-Fixed	C-130	2350	300	50 pax / 30 litt	(none)	2020	Maint. 21st
USA, USN	ARW 12	Darwin: Ft. Jones	Darwin	Tanker	KC-130	2350	300	30 klbs	(none)	2020	E Timor NEO
USA, USN	VLH 1	Darwin: Ft. Jones	Darwin	Transport-Rotor	UH-1N	250	126	8 pax / 5 klbs	(none)	75	Maint. 16th
AUS, RAN	Sqdn 02	Darwin: RANAB	Darwin	Attack-Fixed	F-4	1750	920	(none)	Guns, msls, bmb	3000	Maint. 19th
AUS, RAN	Sqdn 4	Darwin: RANAB	Darwin	Fighter	F-18B	400	>1360	(none)	Guns, missles	5000	Training Fligh
AUS, RAN	Sqdn 12	Darwin: RANAB	Darwin	Transport-Rotor	H-60	380	180	18 pax / 6.4 klbs	2 mgs	75	Maint. 16th
USA, USN	MAW 2	GUAM:NAB	Rabaul	Transport-Fixed	MC-130	2350	300	74 pax / 25 klbs	(none)	2020	Training Fligh

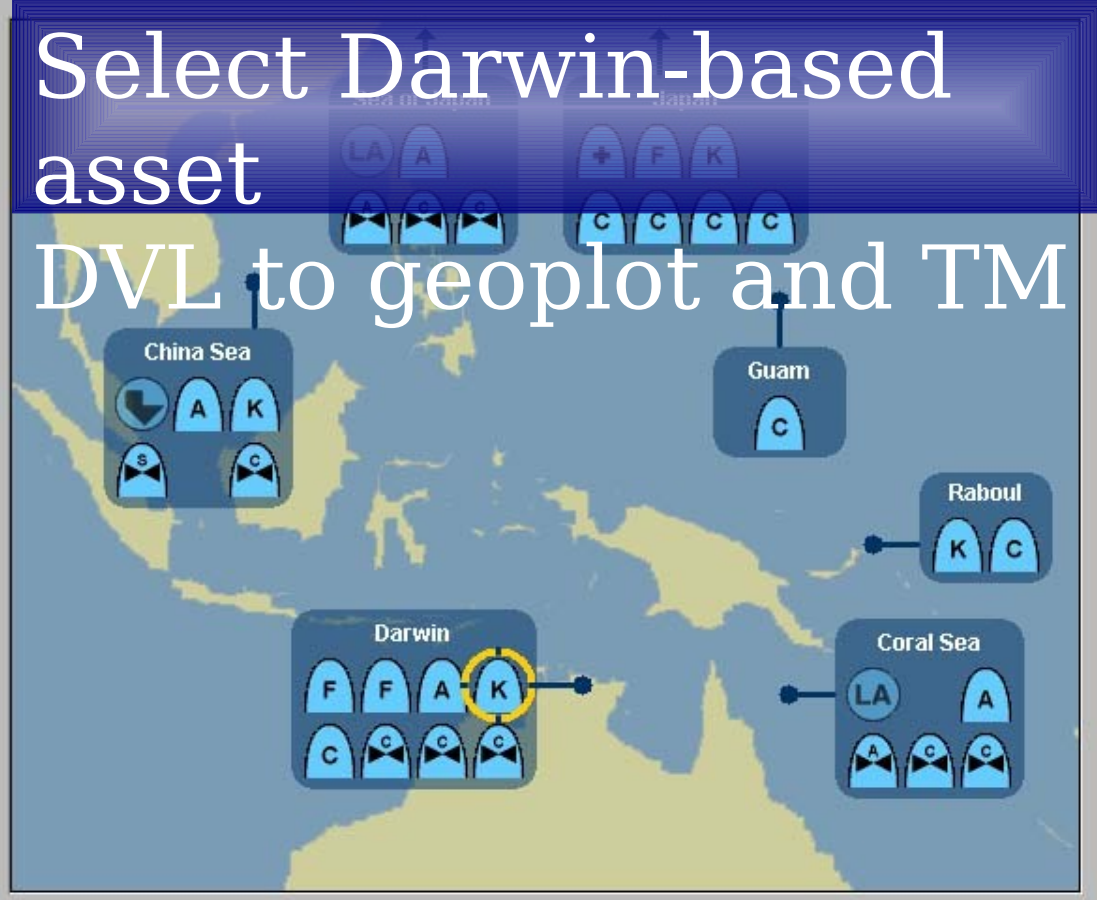
Select Darwin-based asset

DVL to geoplot and TM

Task Viewer

Task	Schedule
Sat 25th - Sun 26th	02 04 06 08 10 12 14 16 18 20 22
Advance party	
Rescue Package	
Extract to FARP	
Extract to Darwin	

Task Resource List



Resource Grid

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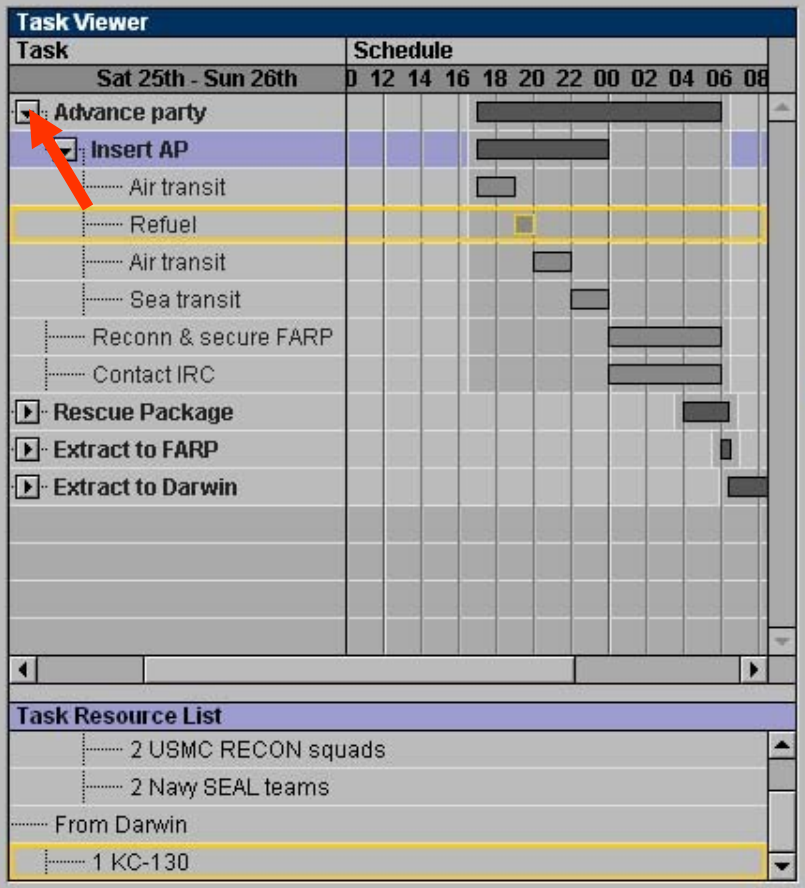
USA, USN	VLH 3	CARGRU 43	CG43: Chi	Transport-Rotor	CH-46	151	166	22 pax / 15 litt	(none)	75	Uncommitted
AUS, RAAF	Sqdn 17	Darwin: Ft. Jones	Darwin	Attack-Fixed	F-4	1750	920	(none)	Guns, bombs	5000	Training Fligh
AUS, RAAF	Sqdn 3	Darwin: Ft. Jones	Darwin	Transport-Rotor	UH-1H	250	126	8 pax / 5 klbs	(none)	75	Uncommitted
USA, USAF	LAW 4	Darwin: Ft. Jones	Darwin	Transport-Fixed	C-130	2350	300	50 pax / 30 litt	(none)	2020	Maint. 21st
USA, USN	ARW 12	Darwin: Ft. Jones	Darwin	Tanker	KC-130	2350	300	30 klbs	(none)	2020	E Timor NEO
USA, USN	VLH 1	Darwin: Ft. Jones	Darwin	Transport-Rotor	UH-1N	250	126	8 pax / 5 klbs	(none)	75	Maint. 16th
AUS, RAN	Sqdn 02	Darwin: RANAB	Darwin	Attack-Fixed	F-4	1750	920	(none)	Guns, msls, bmb	3000	Maint. 19th
AUS, RAN	Sqdn 4	Darwin: RANAB	Darwin	Fighter	F-18B	400	>1360	(none)	Guns, missles	5000	Training Fligh
AUS, RAN	Sqdn 12	Darwin: RANAB	Darwin	Transport-Rotor	H-60	380	180	18 pax / 6.4 klbs	2 mgs	75	Maint. 16th
USA, USN	MAW 2	GUAM:NAB	Rabaul	Transport-Fixed	MC-130	2350	300	74 pax / 25 klbs	(none)	2020	Training Fligh

Expand “Advance Party” task

Refueling task is soon!



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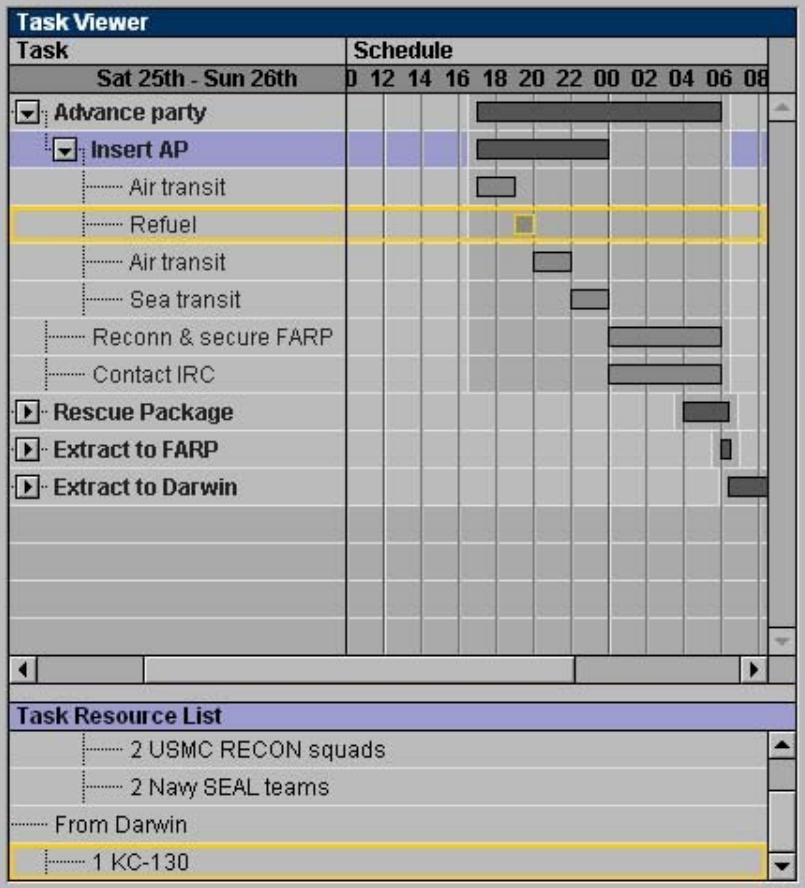
AUS, RAAF	Sqdn 17	Darwin: Ft. Jones	Darwin	Attack-Fixed	F-4	1750	920	(none)	Guns, bombs	5000	Training Fligh
AUS, RAAF	Sqdn 3	Darwin: Ft. Jones	Darwin	Transport-Rotor	UH-1H	250	126	8 pax / 5 klbs	(none)	75	Uncommitted
USA, USAF	LAW 4	Darwin: Ft. Jones	Darwin	Transport-Fixed	C-130	2350	300	50 pax / 30 litt	(none)	2020	Maint. 21st
USA, USN	ARW 12	Darwin: Ft. Jones	Darwin	Tanker	KC-130	2350	300	30 klbs	(none)	2020	E Timor NEO
USA, USN	VLH 1	Darwin: Ft. Jones	Darwin	Transport-Rotor	UH-1N	250	126	8 pax / 5 klbs	(none)	75	Maint. 16th
AUS, RAN	Sqdn 02	Darwin: RANAB	Darwin	Attack-Fixed	F-4	1750	920	(none)	Guns, msls, bmb	3000	Maint. 19th
AUS, RAN	Sqdn 4	Darwin: RANAB	Darwin	Fighter	F-18B	400	>1360	(none)	Guns, missles	5000	Training Fligh
AUS, RAN	Sqdn 12	Darwin: RANAB	Darwin	Transport-Rotor	H-60	380	180	18 pax / 6.4 klbs	2 mgs	75	Maint. 16th
USA, USN	MAW 2	GUAM:NAB	Rabaul	Transport-Fixed	MC-130	2350	300	74 pax / 25 klbs	(none)	2020	Training Fligh

Sort by Mission Type to look for alternative tankers



Resource Grid

Source	Unit	Base Location	Current Location	Mission Type	Plat-form	Range	Speed	Capacity	Armament	Landing Reqs	Status / Availability
USA, USAF	HAW 23	Okinawa	Okinawa	Transport-Fixed	C-141	2800	500	153 pax / 90 klbs	(none)	5000	Team Spirit
USA, USMC	AW 3	Okinawa	Okinawa	Transport-Fixed	MC-130	2350	300	74 pax / 25 klbs	(none)	2020	Team Spirit
USA, USAF	MAW 3	Yokota AB: Japan	Yokota	Transport-Fixed	C-130	2350	300	74 pax / 25 klbs	(none)	2020	Team Spirit
USA, USN	ARW 12	CARGRU 43	CG43: Chi	Tanker	KC-130	2800	300	30 klbs	(none)	2020	Team Spirit
USA, USN	ARW 12	Darwin: Ft. Jones	Darwin	Tanker	KC-130	2350	300	30 klbs	(none)	2020	E Timor NEO
USA, USN	ARW 12	Rabaul: Ft. Smith	Rabaul	Tanker	KC-130	2350	300	30 klbs	(none)	2020	Training Fligh
USA, USN	ARW 12	Yokota AB: Japan	Yokota	Tanker	KC-130	2800	300	30 klbs	(none)	2020	Uncommitted
USA, USN	VF 34	CARGRU 43	CG43: Chi	Fighter	F/A-18	575	>1360	(none)	Guns, msls, bmb	5000	Uncommitted
AUS, RAN	Sqdn 4	Darwin: RANAB	Darwin	Fighter	F-18B	400	>1360	(none)	Guns, missles	5000	Training Fligh
USA, USAF	FW 34	Kadena AB: Japan	Kadena	Fighter	F-15D	3450	1875	(none)	20 mm, 8 missles	5000	Team Spirit

Rabaul-based tanker is available

Task Viewer

Task	Schedule
Sat 25th - Sun 26th	0 12 14 16 18 20 22 00 02 04 06 08
Advance party	
Insert AP	
Air transit	
Refuel	
Air transit	
Sea transit	
Reconn & secure FARP	
Contact IRC	
Rescue Package	
Extract to FARP	
Extract to Darwin	

Task Resource List

- 2 USMC RECON squads
- 2 Navy SEAL teams
- From Darwin
- 1 KC-130

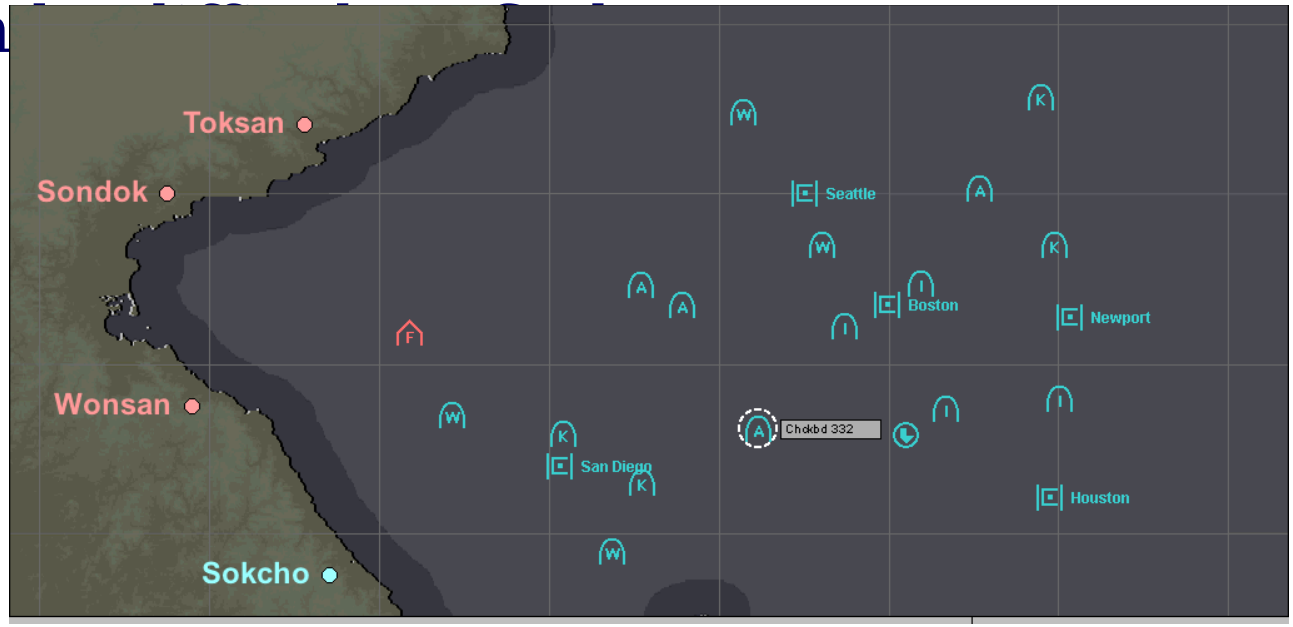
Resource Grid

Source	Unit	Base Location	Current Location	Mission Type	Plat-form	Range	Speed	Capacity	Armament	Landing Reqs	Status / Availability
USA, USAF	HAW 23	Okinawa	Okinawa	Transport-Fixed	C-141	2800	500	153 pax / 90 klbs	(none)	5000	Team Spirit
USA, USMC	AW 3	Okinawa	Okinawa	Transport-Fixed	MC-130	2350	300	74 pax / 25 klbs	(none)	2020	Team Spirit
USA, USAF	MAW 3	Yokota AB: Japan	Yokota	Transport-Fixed	C-130	2350	300	74 pax / 25 klbs	(none)	2020	Team Spirit
USA, USN	ARW 12	CARGRU 43	CG43: Chi	Tanker	KC-130	2800	300	30 klbs	(none)	2020	Team Spirit
USA, USN	ARW 12	Darwin: Ft. Jones	Darwin	Tanker	KC-130	2350	300	30 klbs	(none)	2020	E Timor NEO
USA, USN	ARW 12	Rabaul: Ft. Smith	Rabaul	Tanker	KC-130	2350	300	30 klbs	(none)	2020	Training Fligh
USA, USN	ARW 12	Yokota AB: Japan	Yokota	Tanker	KC-130	2800	300	30 klbs	(none)	2020	Uncommitted
USA, USN	VF 34	CARGRU 43	CG43: Chi	Fighter	F/A-18	575	>1360	(none)	Guns, msls, bmb	5000	Uncommitted
AUS, RAN	Sqdn 4	Darwin: RANAB	Darwin	Fighter	F-18B	400	>1360	(none)	Guns, missles	5000	Training Fligh
USA, USAF	FW 34	Kadena AB: Japan	Kadena	Fighter	F-15D	3450	1875	(none)	20 mm, 8 missles	5000	Team Spirit

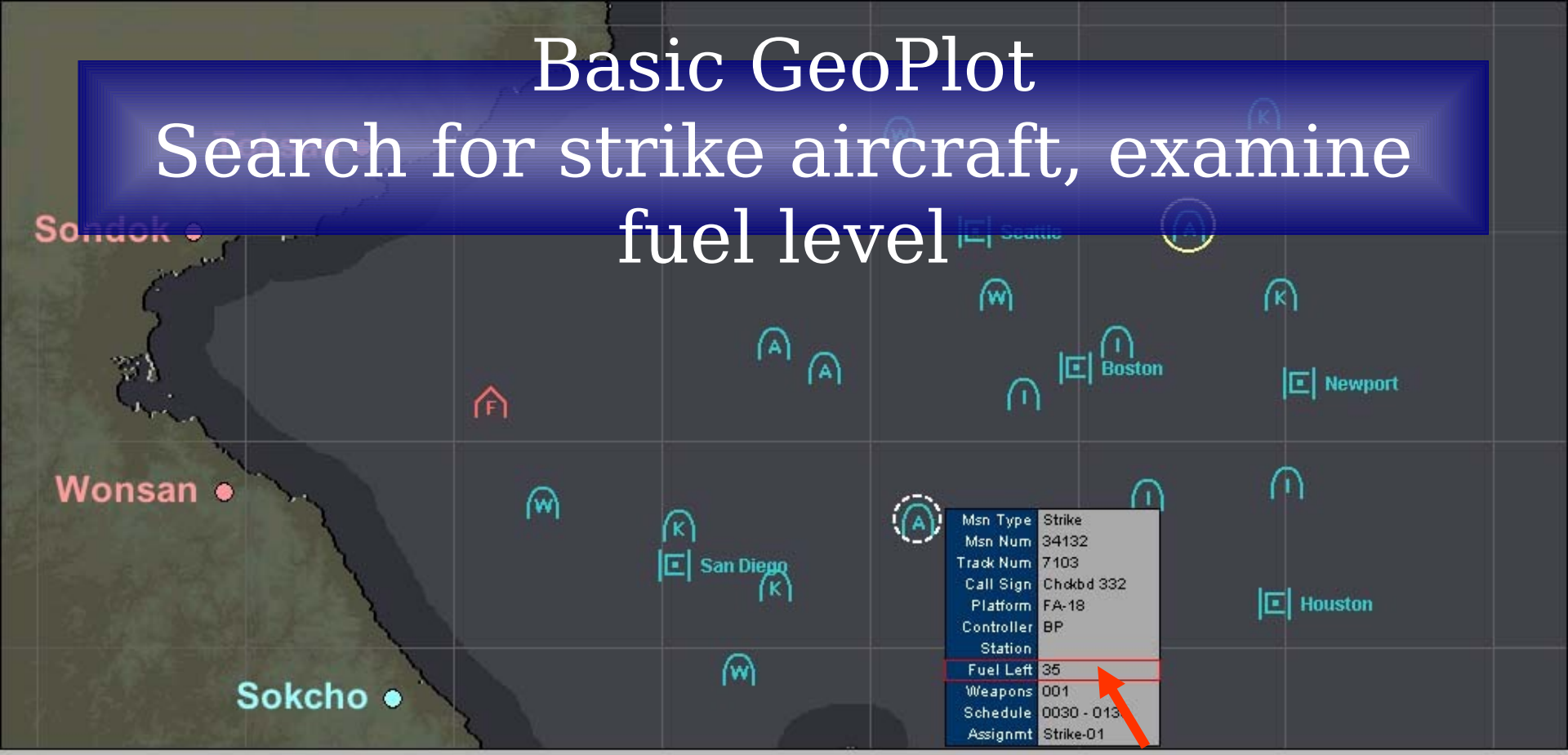
Plans, Assets, & Attributes

- It is difficult to keep track of assets and their status
  - Distilled and organized from multiple sources
- It is difficult to compare the attributes of assets
- It can even

Where is the interceptor with the least fuel?

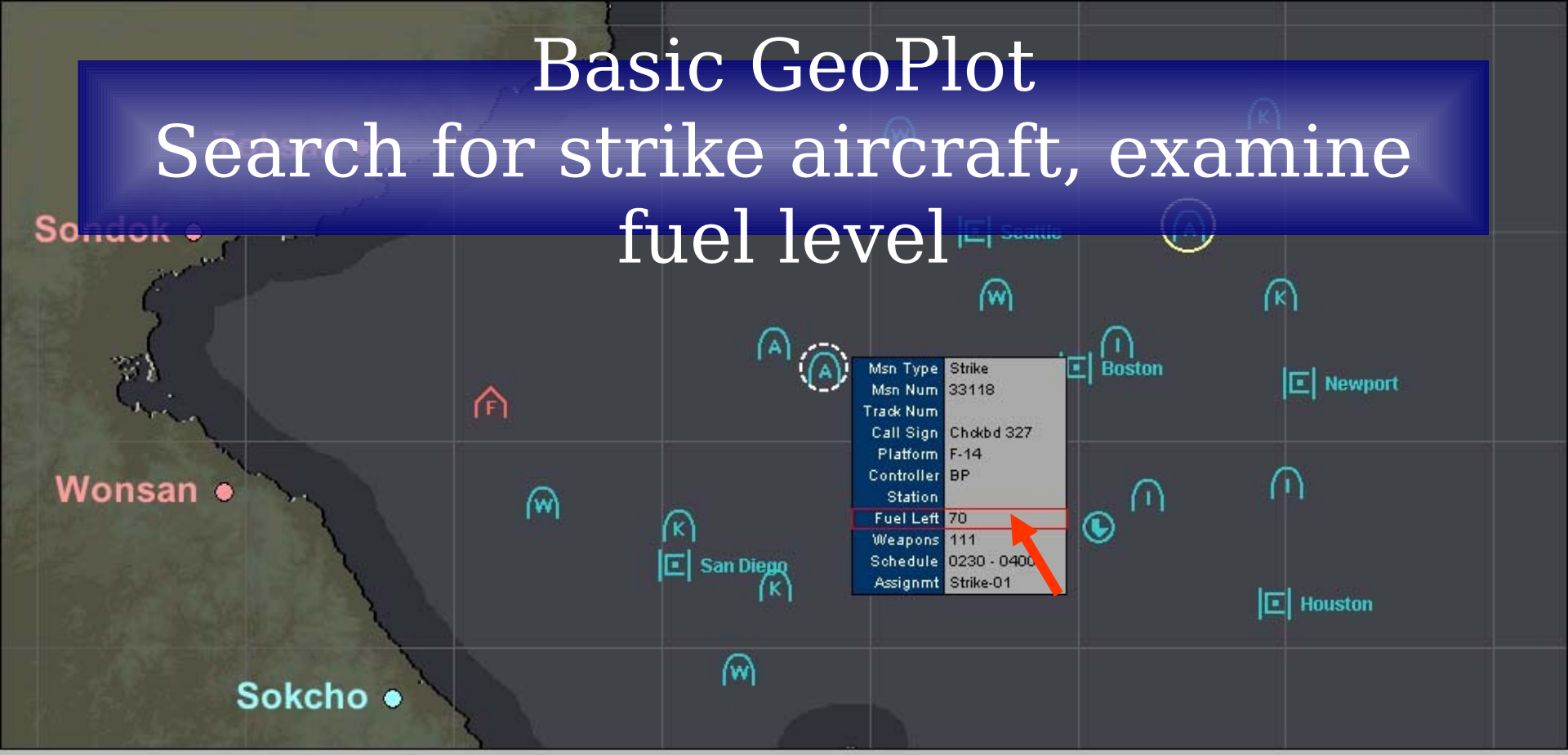


Basic GeoPlot
Search for strike aircraft, examine fuel level



Where is the Strike aircraft with the lowest fuel level?

Basic GeoPlot
Search for strike aircraft, examine fuel level

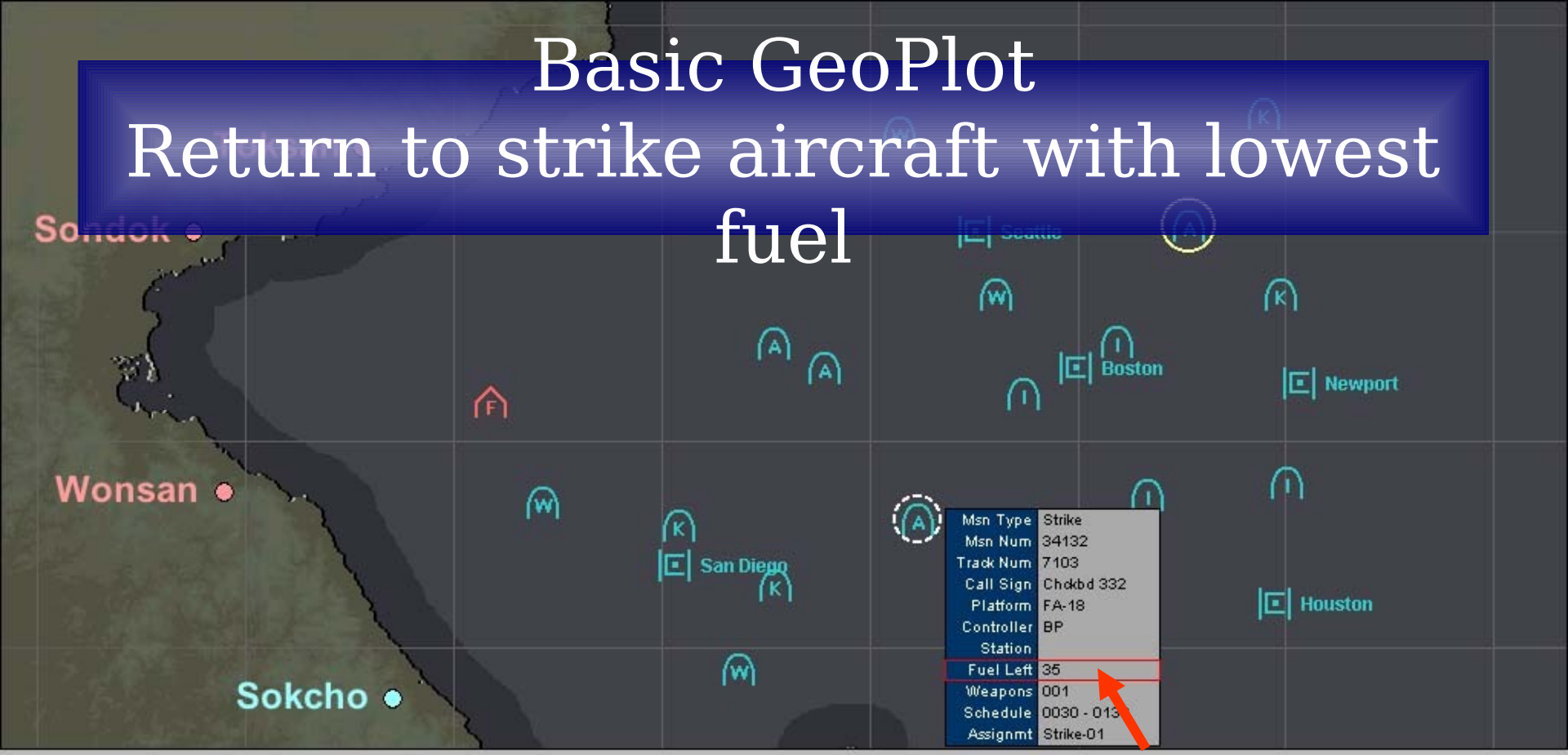


Where is the Strike aircraft with the lowest fuel level?

Basic GeoPlot
Search for strike aircraft, examine fuel level

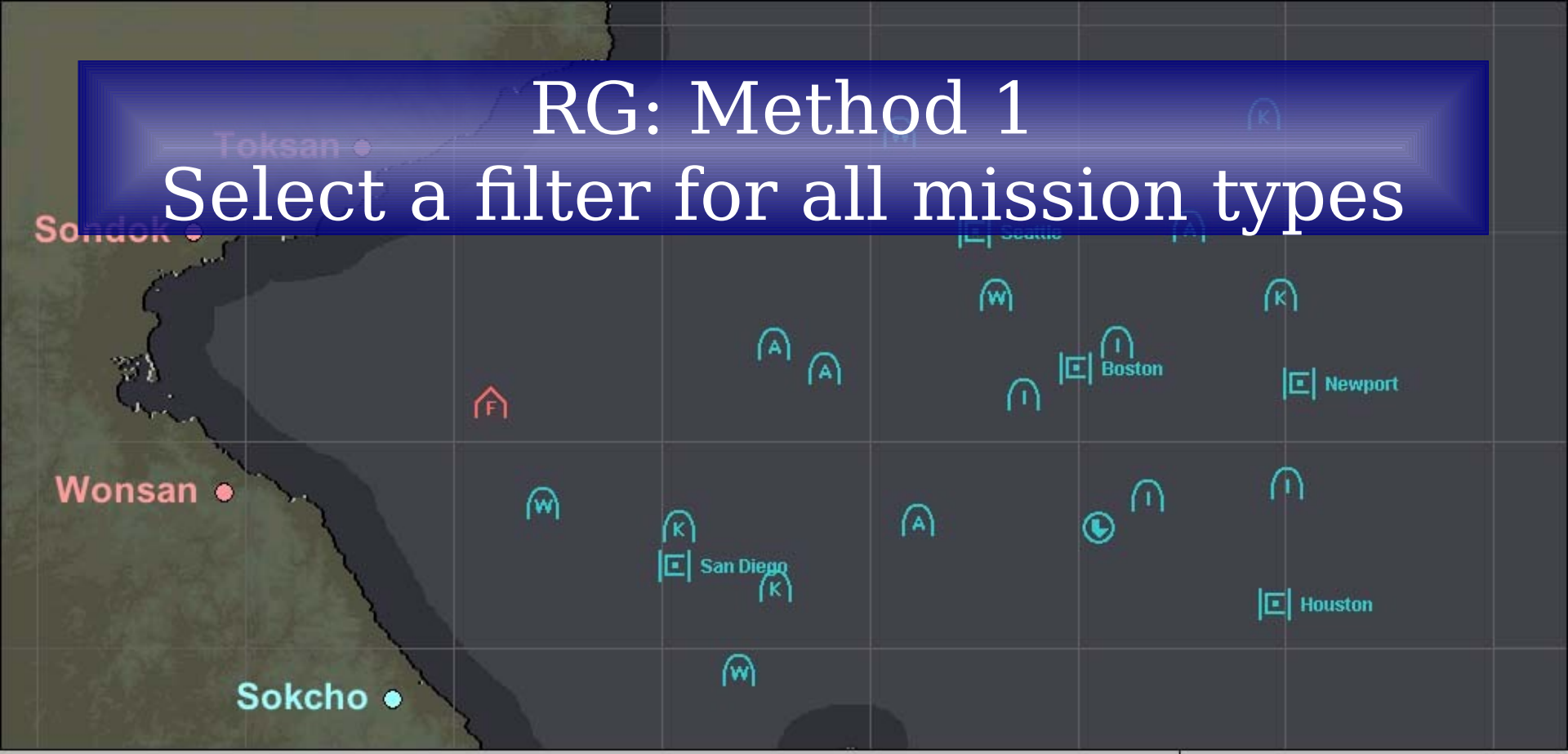
Where is the Strike aircraft with the lowest fuel level?

Basic GeoPlot
Return to strike aircraft with lowest fuel



Where is the Strike aircraft with the lowest fuel level?

RG: Method 1
Select a filter for all mission types

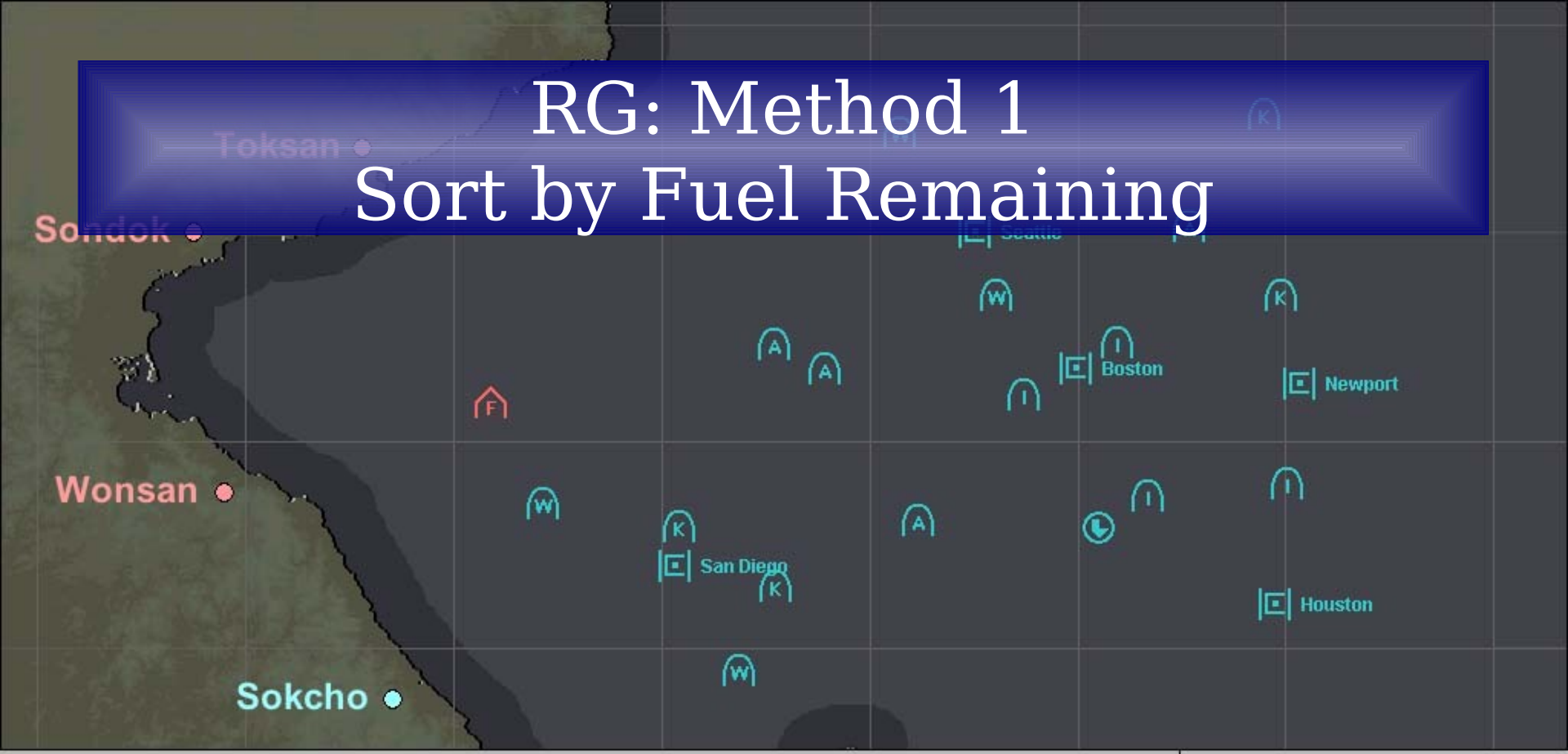


View: ☒ AEW ☒ DCA ☒ Strike ☒ Tanker

Mission Type	Mission Num	Track Num	Call Sign	Platform	Controller	Station	Fuel Remaining (%)	Weapons	Schedule (Z) 03:00	Assignment
AEW	36087	7155	Bear Ace 602	E-2	BW	San Diego	20	000	0130 - 0300	
AEW	36105		Bear Ace 603	E-2	BW	San Diego	80	000	0300 - 0450	
AEW	36138	7187	Bear Ace 610	E-2	BW	Seattle	75	000	0120 - 0220	
AEW	36130		Bear Ace 611	E-2	BW	Seattle	50	000	0130 - 0300	
DCA	33218	7098	Fast Eagle 106	F-14	BW-D	Newport	40	222	0230 - 0400	
DCA	33124		Fast Eagle 110	F-14	BW-D	Newport	20	210	0120 - 0300	
DCA	33138		Fast Eagle 102	F-14	BW-T	Boston	90	020	0230 - 0330	
DCA	33202		Fast Eagle 104	F-14	BW-T	Boston	10	122	0300 - 0450	

Where is the Strike aircraft with the lowest fuel level?

RG: Method 1
Sort by Fuel Remaining



View: AEW DCA Strike Tanker

Mission Type	Mission Num	Track Num	Call Sign	Platform	Controller	Station	Fuel Remaining (%)	Weapons	Schedule (Z) 03:00	Assignment
DCA	33202		Fast Eagle 104	F-14	BW-T	Boston	10	122	0300 - 0450	
DCA	33124		Fast Eagle 110	F-14	BW-D	Newport	20	210	0120 - 0300	
AEW	36087	7155	Bear Ace 602	E-2	BW	San Diego	20	000	0130 - 0300	
Tanker	35066		Scout 706	S-3	BR	Seattle	30	000	0230 - 0400	
Tanker	35093		Scout 701	S-3	BR	Boston	30	000	0300 - 0450	
Strike	34132	7103	Chckbd 332	FA-18	BP		35	001	0030 - 0130	Strike-01
DCA	33218	7098	Fast Eagle 106	F-14	BW-D	Newport	40	222	0230 - 0400	
AEW	36130		Bear Ace 611	E-2	BW	Seattle	50	000	0130 - 0300	

Where is the Strike aircraft with the lowest fuel level?

RG: Method 1
Roll down looking for a strike aircraft

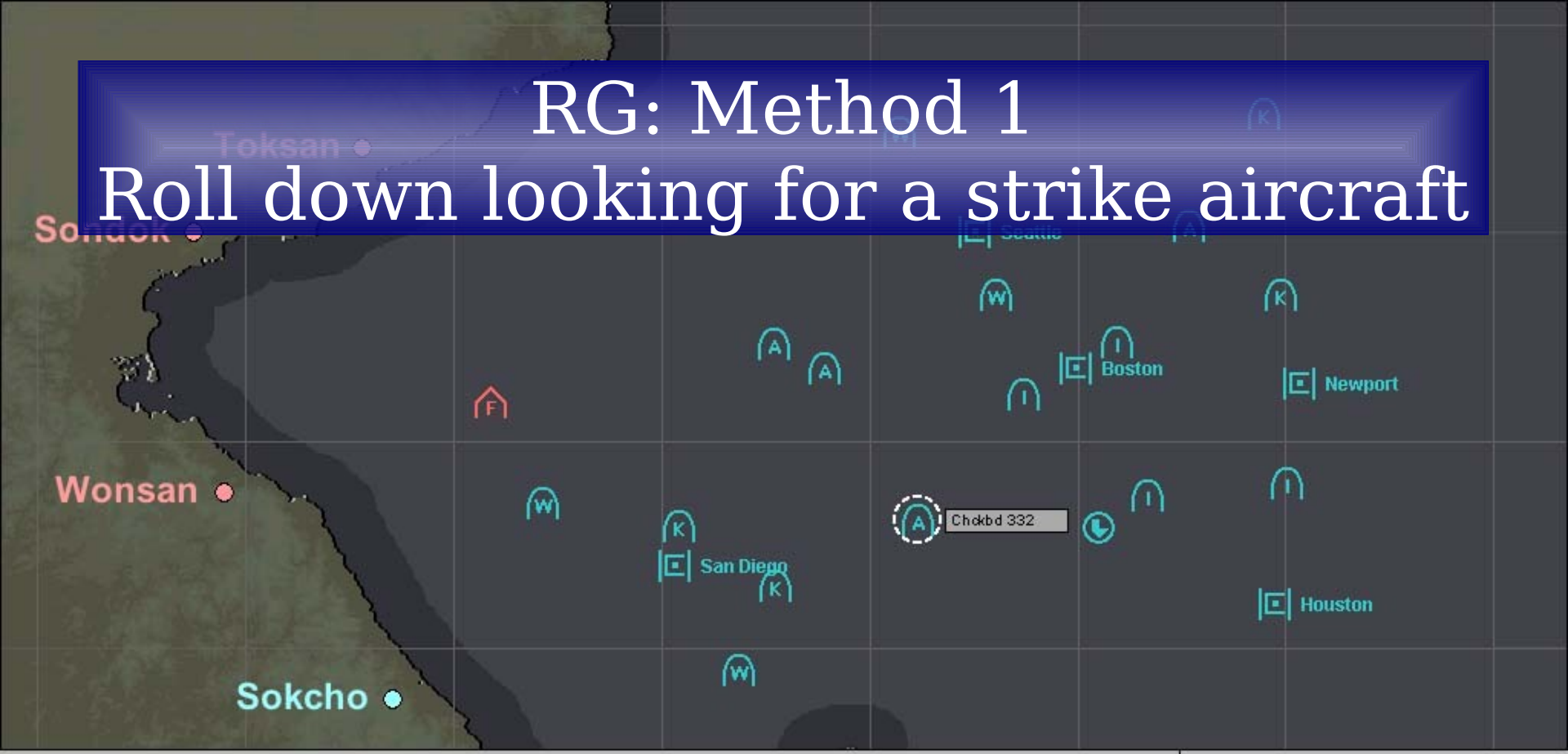
View: ☒ AEW ☒ DCA ☒ Strike ☒ Tanker

DCA	33202		Fast Eagle 104	F-14	BW-T	Boston	10	122	0300 - 0450	

Mission Type	Mission Num	Track Num	Call Sign	Platform	Controller	Station	Fuel Remaining (%)	Weapons	Schedule (Z) 03:00	Assignment
DCA	33202		Fast Eagle 104	F-14	BW-T	Boston	10	122	0300 - 0450	
DCA	33124		Fast Eagle 110	F-14	BW-D	Newport	20	210	0120 - 0300	
AEW	36087	7155	Bear Ace 602	E-2	BW	San Diego	20	000	0130 - 0300	
Tanker	35066		Scout 706	S-3	BR	Seattle	30	000	0230 - 0400	
Tanker	35093		Scout 701	S-3	BR	Boston	30	000	0300 - 0450	
Strike	34132	7103	Chckbd 332	FA-18	BP		35	001	0030 - 0130	Strike-01
DCA	33218	7098	Fast Eagle 106	F-14	BW-D	Newport	40	222	0230 - 0400	
AEW	36130		Bear Ace 611	E-2	BW	Seattle	50	000	0130 - 0300	

Where is the Strike aircraft with the lowest fuel level?

RG: Method 1
Roll down looking for a strike aircraft

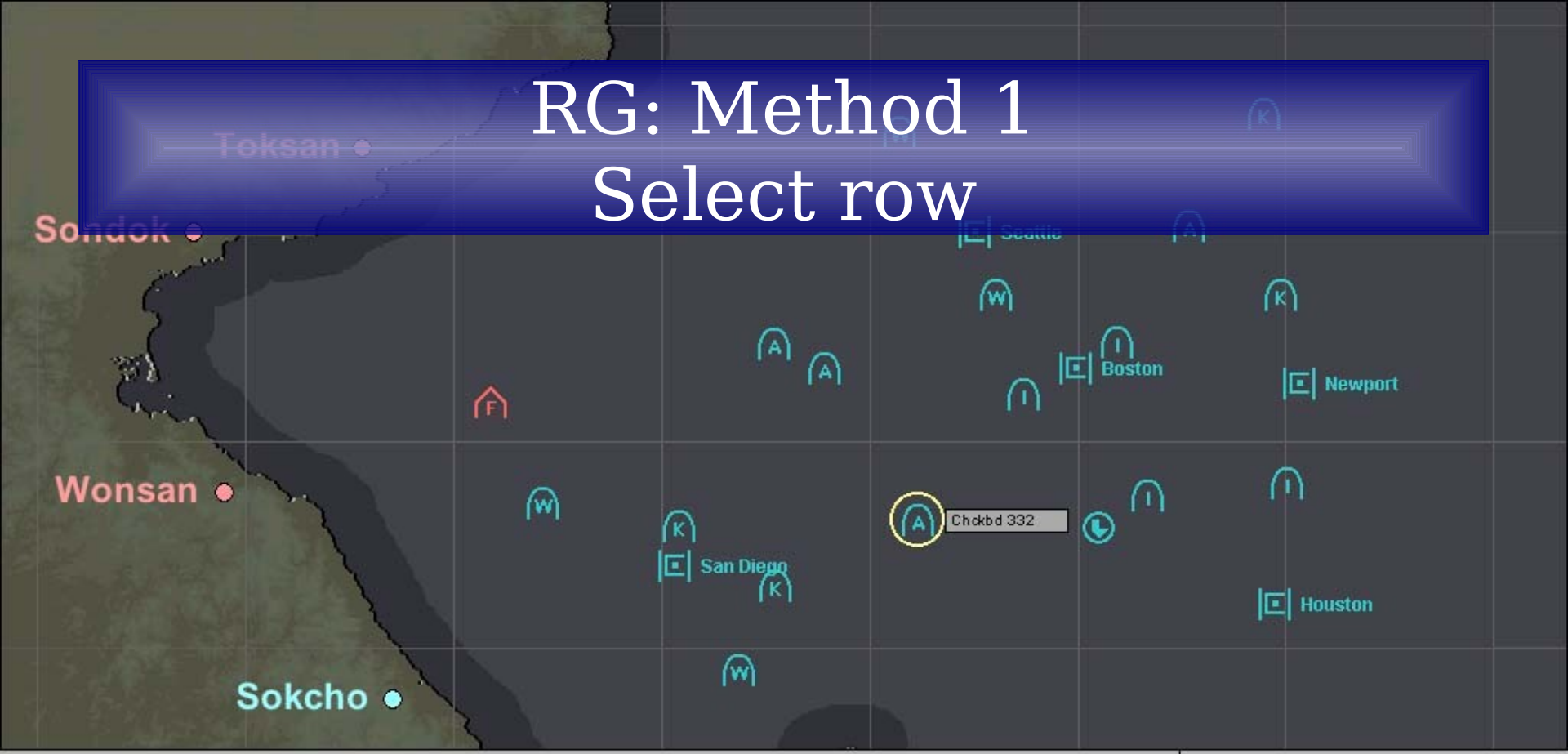


View: AEW DCA Strike Tanker

Mission Type	Mission Num	Track Num	Call Sign	Platform	Controller	Station	Fuel Remaining (%)	Weapons	Schedule (Z) 03:00	Assignment
Strike	34132	7103	Chckbd 332	FA-18	BP		35	001	0030 - 0130	Strike-01
DCA	33202		Fast Eagle 104	F-14	BW-T	Boston	10	122	0300 - 0450	
DCA	33124		Fast Eagle 110	F-14	BW-D	Newport	20	210	0120 - 0300	
AEW	36087	7155	Bear Ace 602	E-2	BW	San Diego	20	000	0130 - 0300	
Tanker	35066		Scout 706	S-3	BR	Seattle	30	000	0230 - 0400	
Tanker	35093		Scout 701	S-3	BR	Boston	30	000	0300 - 0450	
Strike	34132	7103	Chckbd 332	FA-18	BP		35	001	0030 - 0130	Strike-01
DCA	33218	7098	Fast Eagle 106	F-14	BW-D	Newport	40	222	0230 - 0400	
AEW	36130		Bear Ace 611	E-2	BW	Seattle	50	000	0130 - 0300	

Where is the Strike aircraft with the lowest fuel level?

RG: Method 1
Select row

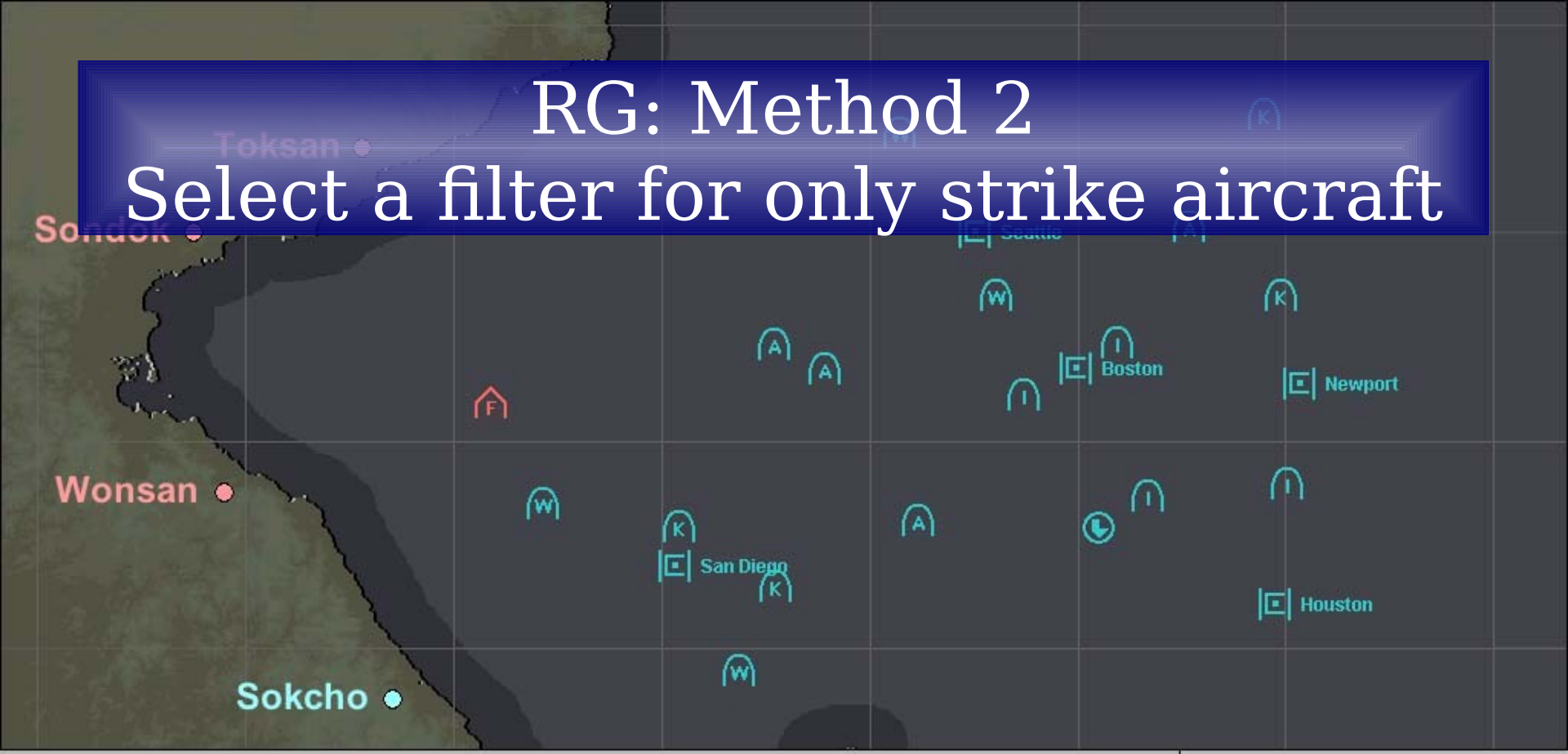


View: AEW DCA Strike Tanker

Mission Type	Mission Num	Track Num	Call Sign	Platform	Controller	Station	Fuel Remaining (%)	Weapons	Schedule (Z) 03:00	Assignment
Strike	34132	7103	Chckbd 332	FA-18	BP		35	001	0030 - 0130	Strike-01
DCA	33202		Fast Eagle 104	F-14	BW-T	Boston	10	122	0300 - 0450	
DCA	33124		Fast Eagle 110	F-14	BW-D	Newport	20	210	0120 - 0300	
AEW	36087	7155	Bear Ace 602	E-2	BW	San Diego	20	000	0130 - 0300	
Tanker	35066		Scout 706	S-3	BR	Seattle	30	000	0230 - 0400	
Tanker	35093		Scout 701	S-3	BR	Boston	30	000	0300 - 0450	
Strike	34132	7103	Chckbd 332	FA-18	BP		35	001	0030 - 0130	Strike-01
DCA	33218	7098	Fast Eagle 106	F-14	BW-D	Newport	40	222	0230 - 0400	
AEW	36130		Bear Ace 611	E-2	BW	Seattle	50	000	0130 - 0300	

Where is the Strike aircraft with the lowest fuel level?

RG: Method 2
Select a filter for only strike aircraft

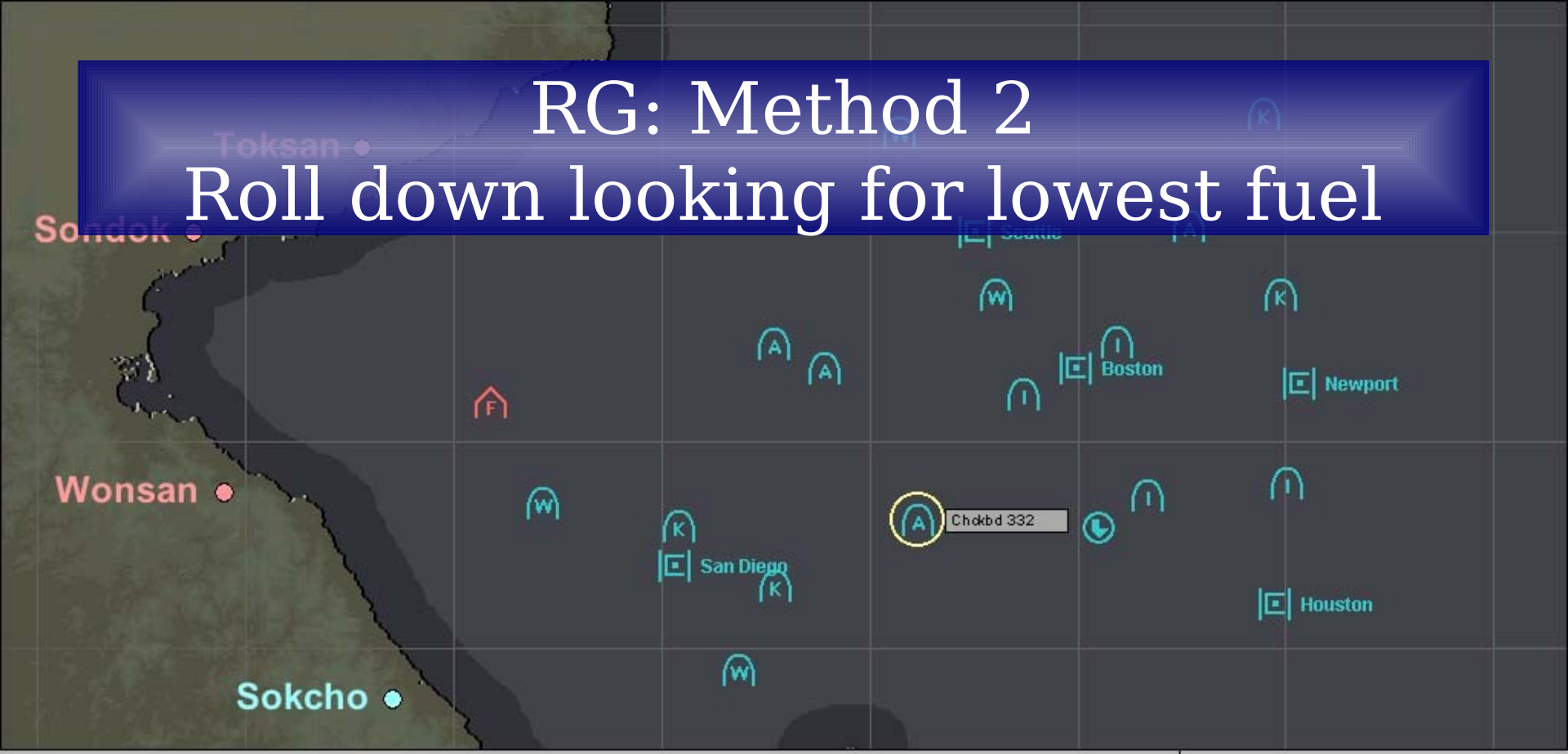


View: ☐ AEW ☐ DCA ☒ Strike ☐ Tanker

Mission Type	Mission Num	Track Num	Call Sign	Platform	Controller	Station	Fuel Remaining (%)	Weapons	Schedule (Z) 03:00	Assignment
Strike	33258	7117	Chckbd 326	F-14	BP		75	120	0300 - 0450	Strike-01
Strike	33118		Chckbd 327	F-14	BP		70	111	0230 - 0400	Strike-01
Strike	34067	7154	Chckbd 331	FA-18	BP		65	122	0130 - 0330	Strike-01
Strike	34132	7103	Chckbd 332	FA-18	BP		35	001	0030 - 0130	Strike-01

Where is the Strike aircraft with the lowest fuel level?

RG: Method 2
Roll down looking for lowest fuel



View: ☐ AEW ☐ DCA ☒ Strike ☐ Tanker

Mission Type	Mission Num	Track Num	Call Sign	Platform	Controller	Station	Fuel Remaining (%)	Weapons	Schedule (Z) 03:00	Assignment
Strike	34132	7103	Chckbd 332	FA-18	BP		35	001	0030 - 0130	Strike-01
Strike	33258	7117	Chckbd 326	F-14	BP		75	120	0300 - 0450	Strike-01
Strike	33118		Chckbd 327	F-14	BP		70	111	0230 - 0400	Strike-01
Strike	34067	7154	Chckbd 331	FA-18	BP		65	122	0130 - 0330	Strike-01
Strike	34132	7103	Chckbd 332	FA-18	BP		35	001	0030 - 0130	Strike-01

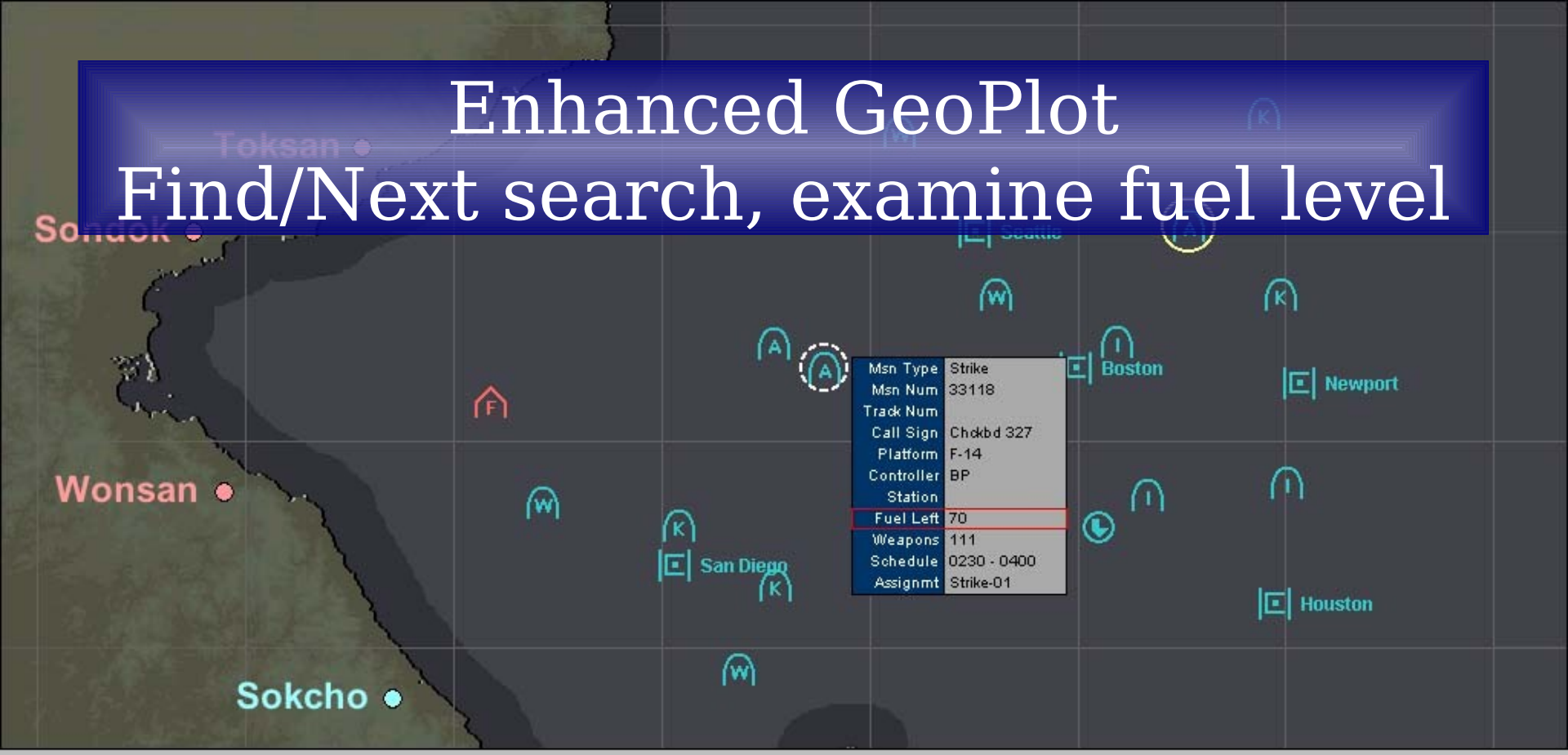
Where is the Strike aircraft with the lowest fuel level?

Enhanced GeoPlot
Find/Next search, examine fuel level

Where is the Strike aircraft with the lowest fuel level?

AEW | DCA | Strike | Tanker

Enhanced GeoPlot
Find/Next search, examine fuel level



Where is the Strike aircraft with the lowest fuel level?

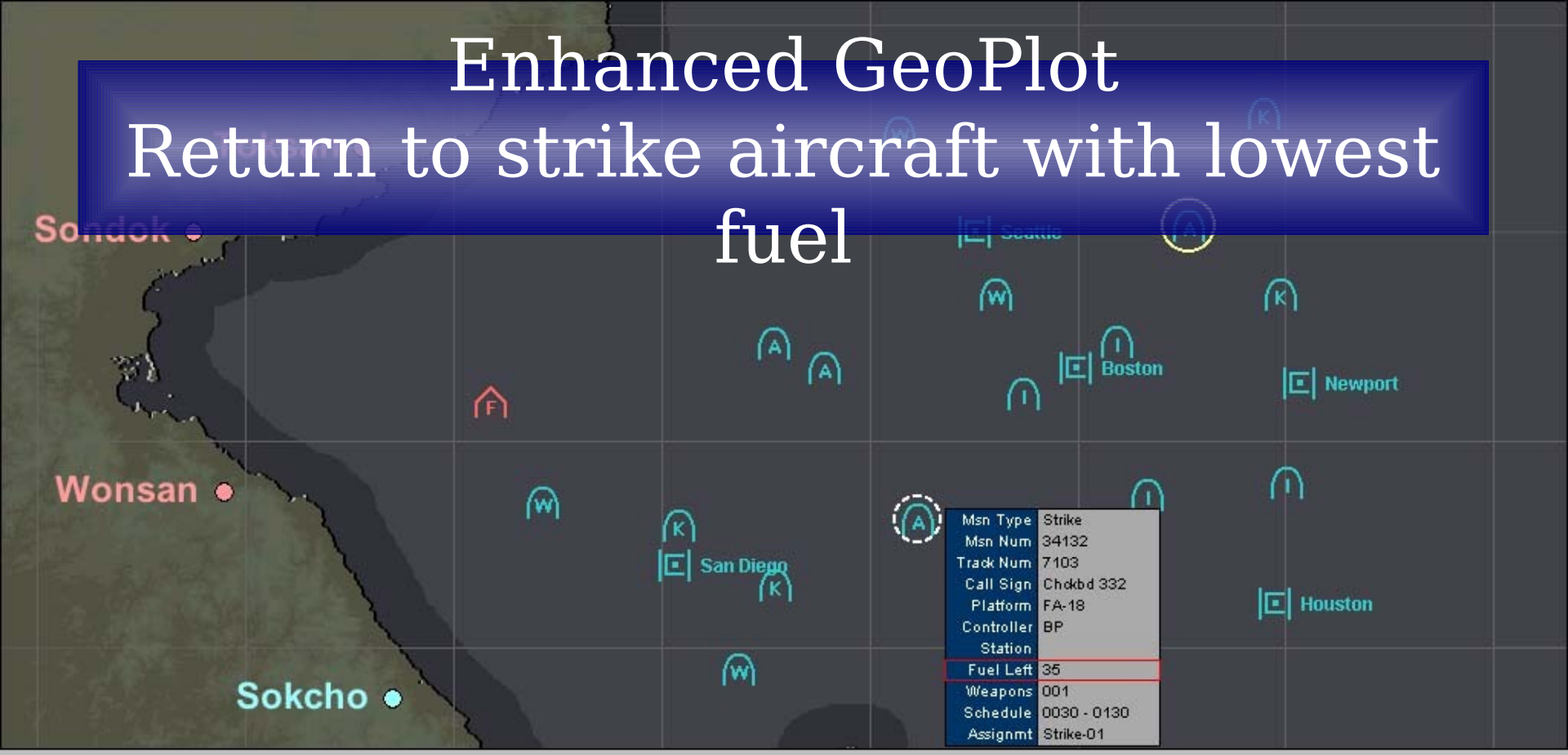
AEW | DCA | Strike | Tanker

Enhanced GeoPlot
Find/Next search, examine fuel level

AEW | DCA | Strike | Tanker

Where is the Strike aircraft with the lowest fuel level?

Enhanced GeoPlot
Return to strike aircraft with lowest fuel

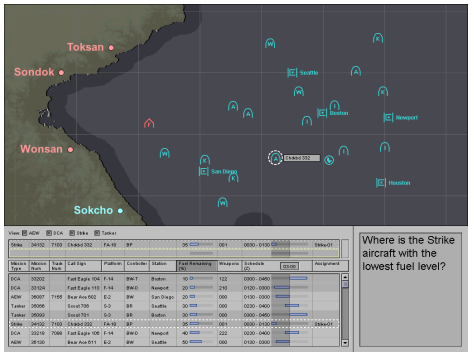


AEW | DCA | Strike | Tanker

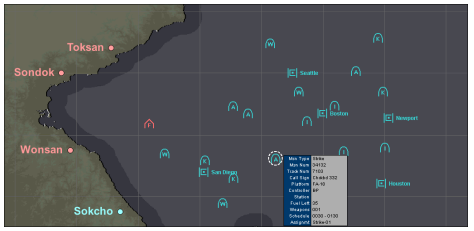
Where is the Strike aircraft with the lowest fuel level?

Design Alternatives for Showing Attributes

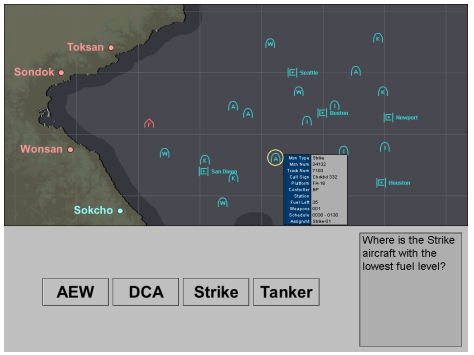
- Resource Grid
  - Tabular and spatial organizations
  - Dynamic visual linking
  - But two displays



- Basic Geoplot plus pop-up list
  - Spatial organization only
  - Single, integrated display
  - But search is difficult

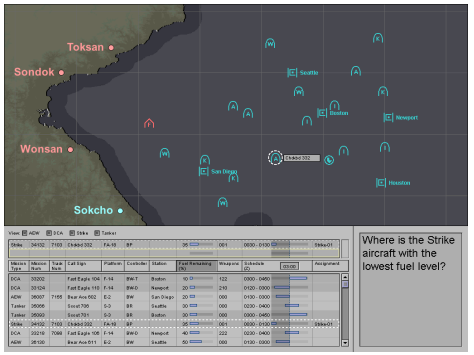


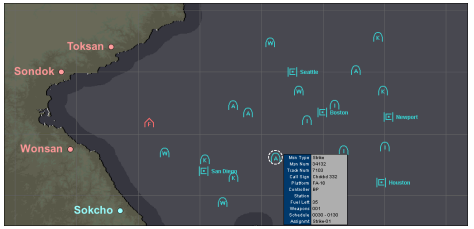
- Enhanced Geoplot
  - Spatial organization only
  - Single, integrated display
  - Find/Next search
  - Still one-at-a-time display

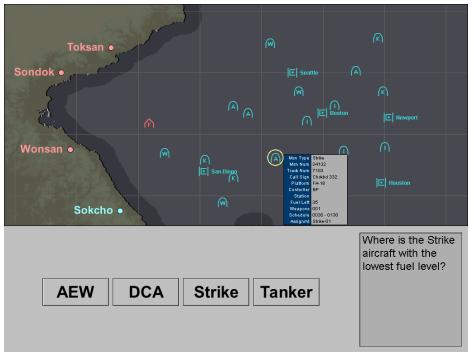


Example Questions from the Experiment

- Data-based search vs. map-based search
  - Where is the aircraft that is closest to the carrier?
  - What is the platform of the aircraft with track number 7022?
- Single attribute vs. comparison
  - Where is the Strike aircraft with call sign Checkerboard 327?
  - What is the call sign of the aircraft with the lowest fuel level?
- Single mission vs. all aircraft
  - Where is the (DCA) aircraft with the fewest weapons?



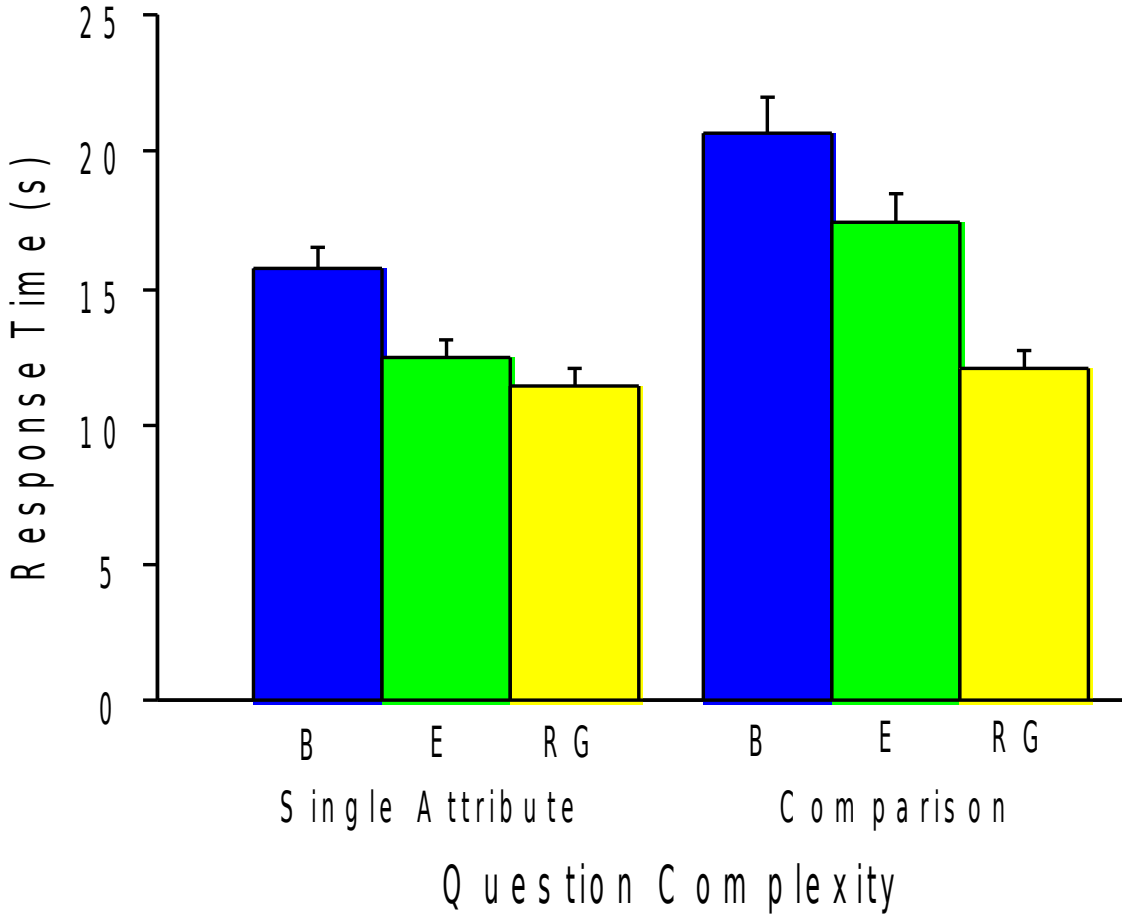




Comparisons Among Assets

Where is the strike aircraft with the lowest fuel level?

- Comparisons were slower than Singles
  - E.g. Searching the geoplot and remembering previous values
- Except for RG
  - Sorting and comparing down a column
- For comparisons, RG was 42% faster than Basic



Conclusions

- Active tables for asset/attribute comparisons
  - Filter-able, sort-able, scan-able tabular display
- Architecture principle: “Slice and Link”
  - Multiple 2D displays, plus
  - Dynamic Visual Linking
- Military command and control is a rich domain for investigation of collaboration principles and innovative visualization concepts
- Many of these principles and concepts apply to multiple domains